Identification of Hazards during Search and Rescue Operations in Cold Climate

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ABSTRACT

A search and rescue exercise simulating the evacuation from a cruise ship in Arctic conditions was carried out jointly between the Norwegian Coast Guard, academic institutions, and participants from the industry, in the north of Spitzbergen in April 2016. Reference for the exercise was the new Polar Code, which came into force in January 2017. This Code is functional, however, it prescribes that survival shall be ensured after 5 days in the evacuated craft. An important part of the exercise was an evaluation of the risks during the use of lifeboats and life rafts; the transfer to the rescue means, the stay in the lifeboats and life rafts and the rescue operation.
The aim of this paper is to present the risks identified for these operations and, their mitigating measures. The focus is to present a review of risks during evacuation and rescue operations in cold climate, evaluate the findings from the exercise, and give a summary of gaps to be closed to meet the requirements of the Polar Code.

KEY WORDS**:** Arctic, cold climate, hazard identification, Polar Code, search and rescue

INTRODUCTION

The International Maritime Organization (IMO, 2016a), has developed the functionally based Polar Code, which came into force on 01 January 2017. The code requires marine operators to provide lifesaving equipment that ensures a minimum of five days' survival time. This requirement puts additional strain on existing lifesaving appliances. The objective of a full-scale rescue exercise, the SARex Spitzbergen, April 2016, Solberg et al. (2016), was to identify and explore the gaps between the functionality provided by existing SOLAS (The International Convention for the Safety of Life at Sea) approved safety equipment (IMO, 2016b) and, the functionality required by the Polar Code. This was performed through an exercise conducted jointly by the Norwegian Coast Guard and leading experts from industry, governmental organizations and academia. The exercise was to be along the lines of a "*Maxim Gorkiy* scenario", where an expedition cruise ship was about to sink in the marginal ice zone off the coast of Svalbard (Hovden, 2012). Figure 1 illustrates the SARex exercise location.
The polar conditions generate additional polar-specific challenges for exercise's participants

and for the lifesaving equipment; these were identified and assessed. In general, the functional requirements, for escape routes states that exposed escape routes shall remain accessible and safe, taking into consideration the potential for icing of structures and snow accumulation. In addition, the survival craft and muster and, embarkation arrangements shall provide safe abandonment of ship, taking into consideration the possible adverse environmental conditions during an emergency. On the other hand, the functional requirements, regarding evacuation states that all life-saving appliances and associated equipment shall provide safe evacuation and be functional under the possible adverse environmental conditions during the maximum expected time of rescue.

Hence, the SARex was aiming to simulate the relevant polar conditions, incorporating sea ice, sea swell, low air and water temperatures and remoteness. Further, SARex was aiming on assessing the possible gaps in the functionality requirements, such as:

i) exposed escape routes may not be accessible or safe, taking into consideration the potential for icing of structures and snow accumulation;

ii) all life-saving appliances might not provide safe evacuation and be functional under the possible adverse environmental conditions and, adequate thermal protection might not be provided for all persons on board;

iii) escape routes and embarkation arrangements might not be arranged for and adequate for persons wearing additional polar clothing;

iv) the lifeboats and life rafts might not have enough space to accommodate persons equipped with thermal protection adequate for the environment, etc.

About SARex

- SARex was a full-scale exercise that sought:
  - To identify and explore the gaps between the functionality provided by existing SOLAS approved safety equipment and the functionality required by the Polar Code.
- The full-scale exercise was held in Woodfjorden in northern Svalbard in late April 2016.

Aim of SARex

- The exercise aimed to simulate relevant polar conditions as well as incorporate:
  - sea ice,
  - sea swell,
  - low air and
  - water temperatures, and remoteness

Figure 1. SARex test location in Woodfjorden, indicated with a red circle. Map © Norwegian Polar Institute

The full report regarding the exercise can be found, Solberg et al. (2016). The rest of the paper is organized as follows: a brief description about the main aim of the SARex research exercise is presented in Section 2. Thereafter, in Section 3, the main findings of the Preliminary Hazard Analysis (PHA) are summarized. Finally, concluding remarks are presented in Section 4.

CASE DESCRIPTION – SARex RESEARCH EXERCISE

Prior to the SARex research exercise, a cross-disciplinary team comprised of medical doctors, suppliers, researchers, academicians, regulators and users, assessed the Polar Code, especially focusing on the interpretation of Chapter 8: Lifesaving Appliances and Arrangements. The main goal of the Chapter 8 of the Polar Code is:

> *"The equipment required by the Polar Code is to provide functionality that enables the individual safety, which means to maintain cognitive abilities, body control and fine motor skills for the maximum expected time of rescue."*

In order to address and investigate the potential gaps, the SARex research exercise was carried out jointly between the Norwegian Coast Guard, academic institutions, and participants from the maritime as well as oil and gas industry. SARex was a full-scale exercise that was held in Woodfjorden in northern Svalbard in late April 2016. In general, the main objectives of the exercise and the associated research trip were to:

- Assess the adequacy of the lifesaving appliances as required by the IMO Polar Code.
- Identify the gaps between SOLAS approved rescue craft (lifeboats and life rafts) and the requirements defined in the IMO Polar Code.
- Identify the gap between SOLAS approved personal protective equipment (PPE) and the requirements defined in the IMO Polar Code.
- Assess the personal/group survival kits as defined by the IMO Polar Code.
- Train Norwegian Coast Guard personnel in emergency procedures in ice-infested waters, with particular reference to evacuation and rescue from cruise ships.

Moreover, the exercise addressed the following topics (Solberg et al., 2016):

- functionality of life raft/lifeboat under polar conditions;
- functionality of personal protective equipment (PPE) (e.g. thermal protection/survival suits);
- additional training requirements for crew and passengers;
- evaluation of Coast Guard's search and rescue procedures, including handling of mass evacuations in Polar Regions.

The exercise was carried out in three phases:

- *Phase one:* Testing survival times in lifeboat and life raft with participants wearing different kinds of personal protective equipment.
- *Phase two:* Training for the Coast Guard personnel on mass evacuation from lifeboat and triage of passengers.
- *Phase three:* Testing the lifeboat and life raft in ice-infested waters as well as testing personal/group survival equipment and personal protective equipment on ice/close to ice.

Figure 2. Lifeboat being lowered into the water with the deck crane. Photo © Jan Erik Jensen

As a part of the preparations for the exercise, the lifeboat was launched from the deck of KV Svalbard using the deck crane (Figure 2). In addition, transport between KV Svalbard and the survival crafts was carried out using the two MOBs (Man Overboard Boats), and these were also utilized for toilet breaks. Moreover, there were at least one MOB boat stationed close to the survival crafts during the exercise for safety reasons. The exercise was started Sunday 24th of April, at approximately 09:40, when all participants had been transported to the lifeboat/ life raft with the MOBs. The weather during the exercise was ideal for performing the exercise, with an ambient air temperature of about –9°C, a water temperature of about –1°C and little wind. These are considered representative weather conditions for the cruise ship season in Svalbard. Due to the favorable weather conditions, seasickness was not an issue for any of the participants.

The lifeboat and life raft employed for the exercise as well as PPEs, which the participants wore during the exercise are depicted in Figures 3 to 6. In phase 1, each participant wore standard SOLAS approved PPEs, ranging from life jackets to insulated survival suits. The goal was to see how long the participants would stay in the lifeboat before they experience the cold stress – the response of the body to cold temperatures resulting from heat loss. The heat loss can be due to whole-body cooling and/or local cooling, including extremity cooling, convective skin cooling, conductive skin cooling (contact cooling), and cooling of respiratory tract.

Figure 3. The lifeboat and the raft © Trond Spande

Figure 4. Lifeboat drifted into a belt of ice during the exerciseoto © Trond Spande

Figure 5. Situation inside the lifeboat © Bjarte Odin Kvamme

Figure 6. Situation inside the raft. People with survival suits are warm, and had to open their suit to avoid sweating. © Jan Erik Jensen

PRELIMINARY HAZARD ANALYSIS

In general, in polar waters – in Arctic water – it is not enough to keep people afloat with either life jackets, lifeboats or life rafts. People must also be kept dry and warm to be able to survive in such a harsh climate. With a maximum expected time of rescue of five days, it is also important that people have access to food and water to sustain them for this time. The most important life-saving appliances in polar waters is the immersion suit and, a lifeboat/ life raft stocked with the necessary equipment. In addition, in case of a wet evacuation, an immersion suit together with personal survival equipment is crucial to survival, but even then, people cannot survive for long if they cannot get into a lifeboat/ life raft or onto land or ice.

Further, in an evacuation situation, in Arctic water, getting to the lifeboat/ life raft can be hazardous if the walkways are unsheltered and slippery due to ice and snow accumulation. For instance, cruise passengers are often elderly persons that can have a difficult time moving around and, they can be in need of some sort of assistance. In these cases, a slippery walkway can be a daunting task to maneuver through safely. The Polar Code requires exposed escape routes to be accessible and safe when taking into consideration the potential for icing of structures and snow accumulation. This can be achieved with sheltered walkways. Hence, to ensure that the life-saving appliances are functional under any circumstance in the Arctic, they have to be designed to work with the presence of low temperatures, snow and ice. Further, the Arctic cruise ship industry should work towards fulfilling the goals with life-saving appliances that meets all the functional requirements of the Polar Code.

To maximize the chances of prolonged survival in polar waters, the potential hazards and risks in case of accident should be investigated and, risk reduction as well as mitigation measures should be assessed. In order to fulfil these aims, during SARex efforts were done to evaluate the potential hazards and risks under Arctic conditions. Further, for ensuring the safety of the participants, after the exercise, all those participating in the exercise were taken back to KV Svalbard as soon as one or more of the predefined abortion criteria was met. The predefined abortion criteria were defined as:

- Loss of cognitive abilities
- Loss of body control (e.g. uncontrollable shivering)
- Loss of fine motoric skills

Further, since the participants aborted at different times, the ship's medical doctor was on stand-by during the entire exercise period. Immediately after returning to KV Svalbard, the following medical parameters was checked on all participants: body temperature, pulse, and blood pressure.

Functionality of Life Raft/Lifeboat Under Cold Climate Conditions

The evacuation from the Coast Guard vessel *KV Svalbard* was performed with the help of the vessel's man overboard boats (MOBs). The transfer of the survivors from the lifeboat and life raft to the vessel was also carried out by MOBs. The hazard prior to the evacuation of personnel to the lifeboat and life raft were identified and, the potential consequences are discussed.

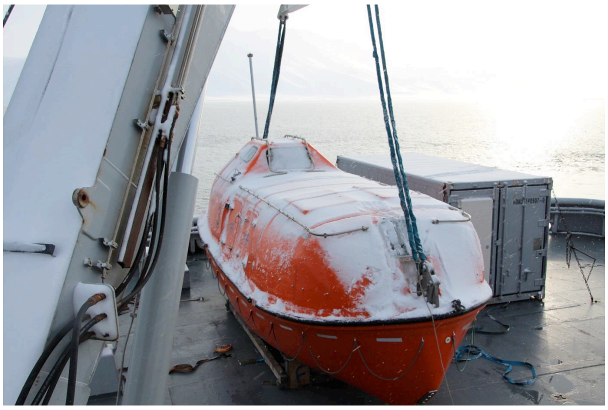

Figure 7. The lifeboat experienced snow accumulation during the exercise. © Trond Spande

Thereafter, risk-reducing measures were suggested. For instance, when launching a lifeboat under Arctic conditions, one of the main risk factors are icing on the parts and components (Figure 7). In cases of icing, a lifeboat is unable to launch properly, which consequently leads to drastically reducing the passengers' survival chances. To reduce the impact of icing, employing risk-based inspection procedures and manual ice removal as a risk reduction measures should be considered. Further, enclosing life rafts and lifeboats as well as implementing heating systems can be effective risk reduction measures.

Table 1 illustrates an example of the risk assessment for the transfer to the lifeboat. The hazard identification was considered essential for the safety of those involved in the exercise and the complete assessments are presented in Appendix (Table A1 and Table A2). The lifeboat, which was employed for testing in the SARex project was a conventional Totally Enclosed Lifeboat (TELB) with model name "Miriam 8.5", and was designed and manufactured in accordance to the latest SOLAS, Classification Society and National Authority requirements. In addition, the lifeboat was equipped with a compressed air system and exterior deluge system and, seating inside the lifeboat consisted of GRP (glass fiber reinforced plastics) benches with safety belts. Moreover, the lifeboat was launched and retrieved using a davit, with two lifting wires, which connected to the lifeboats' two release hooks. Further, when installed on a ship's side, the lifeboat is equipped with skates that allows it to slide easily on the ships' side, along with shock-absorbing fenders.

Table 1. An example of SARex Phase 1 Risk assessment – lifeboat

Potential hazard	**Cause**	**Consequence**	**Risk-reducing measures**
Rescuing passengers from sea to lifeboat	Insufficient arrangements on lifeboat for extraction of people. Mob boat far away.	Difficult/impossible to rescue survivors from sea	Mob boat nearby.
Transfer of persons from lifeboat to rescue vessel	-Insufficient/no arrangements for moving passengers from one craft to another -Passengers have physical problems after long time in lifeboat -Heavy seas/strong winds	Complicated rescue process, potential injuries/fatalities Time consuming 30 minutes?	Helmet Evenly distribute the weight in the mob boat Hold onto the rail in the boat
Danger getting down to lifeboat	Hoisted down in mob boat	Falling into sea/injury	Helmets, life-vest or survival suit, instructions on holding on while lowering.
Falling into sea	Transfer of persons between lifeboat and mob boat. Trying to urinate from either lifeboat or mob boat.	Becoming soaking wet and very cold. Exercise over for that person.	Assistance from mob boat crew. Mob boat always nearby, *KV Svalbard* also nearby.
Tripping and falling	-Passengers not used to heavy suits/equipment -Slippery surfaces	-Fall damage (injuries, broken bones) -Ending up in the water	-Be cautious -Follow instructions -Detailed safety information and procedures from *KV Svalbard* crew
MOB boat lifting hook swinging after release	-Hook operator error -Rough seas	-Hook arrangement hits passengers in MOB boat, leading to injuries.	-Follow instructions -Detailed safety information and procedures from *KV Svalbard* crew
Exercise participant becomes ill/injured needs immediate assistance	Decease, accident, medical issues.	They are in need of medical assistance.	Mob boat nearby, *KV Svalbard* nearby. Helicopter from Longyearbyen next option.
Personal protective equipment not functioning	Damaged, production error, not maintained correctly.	PPE does not work as intended.	Maintenance &functionality check before use.

The lifeboat exercise also highlighted several potential hazards and possible gaps. For instance, one of the highlighted problems was mist build-up that led to poor sight, which was due to mist building up on the inside of the lifeboat windows. This mist build-up forced the coxswain (the person in charge of the navigation) to wipe the windows continuously to be able to see the external environment. Further, inside the lifeboat, the air quality and low oxygen levels were issues, as the ventilation system required the engine to be operating. In addition, the participants experienced a significant heat loss from the structure (floor, seat and backrest) of the lifeboat. Hence, for improving the performance of the lifeboat, various measures should be implemented. For instance, to reduce the mist build-up, heating in the windows and air vents should be considered. Further, to obtain a survivability rate in accordance with the minimum five-day requirement set by the Polar Code, the insulation system of the lifeboat in combination with the insulating capabilities of the personal protective equipment should be improved.

In addition to evaluating the functionality of lifeboats, during the SARex exercise, the potential hazards and possible gaps that are associated with life rafts were investigated. Table 2 illustrates an example of risk assessment for life rafts. Several potential hazards and possible gaps were highlighted during the SARex exercise. One of the main issues was that the participants in the life raft experienced a significant heat loss, especially through the bottom of the life raft. This became especially evident when sitting or lying down, regardless of the type of personal protective equipment used. To reduce the heat loss, the life raft canopy was kept closed to retain heat. Consequently, the lack of ventilation caused the air to be moist, and extensive condensation developed. Thereafter, due to the combination of condensation and sweat, survivors suffered from wet insulation layers in their PPEs, followed by loss of insulation and freezing. Moreover, low oxygen levels were also an issue, and the raft had to be vented frequently, losing a significant amount of heat in the process. Furthermore, the congestion inside the raft was a problem, causing reduced ability to move, triggering reduced blood circulation in the body's extremities, resulting in freezing hands and feet.

Table 2. An example of SARex Phase 1 Risk assessment – Life raft

Potential hazard	**Cause**	**Consequence**	**Risk-reducing measures**
Life raft integrity compromised	-Collision with ship during/after launch -Collision ice floes	-Water intrusion, exercise stopped	-Abortion if the ice conditions gets too severe -Procedures for rapid evacuation of all participants
Transfer of persons from life raft to rescue vessel	-Insufficient/no arrangements for moving passengers from one craft to another -Passengers have physical problems after long time in life raft -Heavy seas/strong winds	-Complicated rescue process -Potential injuries/fatalities -Time consuming	-MOB boats will be used for transfer of passengers from life raft to *KV Svalbard*, piloted by experienced crew.
Tripping and falling	-Passengers not used to heavy suits/equipment -Slippery surfaces	-Fall damage (injuries, broken bones) -Ending up in the water	-Be cautious -Follow instructions -Detailed safety information and procedures from *KV Svalbard* crew
Communication difficulties	-Wind noise -Many people talking at the same time -Routines for how to communicate -Radio equipment failure	-Important messages cannot be communicated via radio	-Backup radio equipment/battery -Clarify communication routines prior to test
Sea spray into life raft	-The life raft canopy are open (ventilation, toilet breaks, extracting persons from sea, etc.)	-People get wet and cold -Water enters the life raft.	-Keep canopy closed whenever possible
Sea spray icing on life raft	-Sea spray combined with low temperatures	-Change in life raft buoyancy qualities -Zippers and other small details frozen stuck	-Shaking canopy from the inside to loosen any ice
Clogging/blocking of ventilation	-Warm and moist air from inside the life raft condensates and freezes around/in the ventilation outlet	-Reduced ventilation -Deterioration of air quality	-Opening canopy for ventilation

From the risk assessment results of the SARex exercise, it can be deduced that it is unlikely that the majority of those evacuated to a life raft and lifeboat (engine shut off) would survive for a minimum of five days according to the Polar Code criteria. In addition, the presence of a well-trained lifeboat/life raft captain proved very important for maintaining both the safety and, the morale of the personnel on board. This is especially important when the duration of the stay is long (a minimum of five days, along the lines defined in the Polar Code). Further, due to the high risk of cardiac arrest connected to hypothermia, having a defibrillator onboard is recommended. However, this is costly and someone on board the lifeboat would have to know how to use it. The Polar Code does not address the medical problem, but the cruise operators and their organizations will need to consider it carefully.

In addition, when it comes to having a habitable environment, seasickness and hygiene issues have to be addressed. For instance, seasickness can make the lifeboat an uncomfortable place to be, as well as cause dehydration and starvation. Especially water is crucial; little water in combination with seasickness can easily lead to dehydration. Further, it should be noted that most of the people involved in the SARex exercise were either physically fit young persons or mature persons with good physical health. The lack of elderly or disabled persons involved in the exercise renders the results on the positive side, as the participants were apt and, in better physical and physiological shape than the average seafarer/ passenger. Seasickness was not an issue in this exercise, as the waters were calm, and all participants were given seasickness pills to prevent any occurrence of vomiting.

Handling of Mass Evacuations in Polar Regions

One element of the SARex was to require the Coast Guard staff to conduct a mass evacuation from the rescue craft onto the Coast Guard vessel. A large number of the evacuated personnel simulated a hypothermia state. Establishing, implementing, and conducting regular training on the procedures for handling disabled, wounded, and immobile passengers when evacuating a large group of people is of great importance for ensuring an efficient evacuation. Evacuating a large number of immobile casualties takes an excessive amount of time and, puts a great strain on the staff on board the Coast Guard vessel. The medical state of the casualties is of key importance in determining the time required to evacuate personnel from a lifeboat/life raft to a rescue vessel. The potential of involving those casualties who are in good condition in monitoring/aiding the caretaking process of the patients should be emphasized.

CONCLUSIONS

This paper has presented results from the SARex research exercise, which was carried out to identify and explore the gaps between the functionality provided by existing SOLAS approved safety equipment and, the functionality required by the new Polar Code. The exercise demonstrated that the peculiar Arctic operating environment will have a significant impact on the functionality of the lifeboats and life rafts. In addition, high wind speeds, low temperatures, fog and large waves all create their own set of problems. Moreover, the available radio links and satellite communication in the Arctic lacks in reliability, and therefore presents a safety hazard in major accident scenarios. Further, SARex demonstrated that mass evacuation can be demanding and, in cases of a crowded lifeboat and life raft, it became challenging for the rescue personnel to evacuate the most injured people first, due to the limited available space in the lifeboat/ life raft. In such scenarios, the rescuers were forced to get the people that were able to help themselves off first so they had room to handle the people that required assistance. Furthermore, abandoning a ship in Arctic will require that every person on board have access to life-saving appliances designed for polar waters. Hence, to maximize chances of survival: all passengers will want to be in an enclosed lifeboat if they manage a dry evacuation, or in case of a wet evacuation, an insulated immersion suit designed for polar water survival. The chances of prolonged survival in polar waters will be drastically reduced without these life-saving appliances.

Our conclusion is that in order to fulfil the minimum functional requirement, especially the requirement of Polar Code Chapter 8, which states that a vessel is to provide equipment that enables the passengers to survive a minimum of five days or the anticipated time of rescue, a holistic safety management approach is required. This ensures that the vessel owner considers all relevant conditions, factors and parameters. In general, when assessing the probability of survival, it is recommended to consider the following list of conditions, factors and parameters:

- governing metocean (meteorological and oceanographic) conditions for the area of operation,
- remoteness,
- available SAR infrastructure,
- performance of SAR operators,
- energy required to maintain the core temperature of the persons,
- water/food required to maintain an adequate metabolism for human heat generation,
- safe transfer and stay in the rescue means,
- insulating properties of the rescue craft,
- insulating properties of the PPEs,
- number of passengers and physical condition of the passengers,
- cumulative weight of group and personal survival equipment and carrying capacity of survival craft,
- abandon ship activities,
- survival strategies onboard the evacuation vessel,
- survival craft management, etc.

ACKNOWLEDGEMENTS

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Appendix

Table A1. SARex Phase 1 Risk assessment – Lifeboat

Potential hazard	Cause	Consequence	Risk-reducing measures
Maneuvering difficulties	Heavy sea, sea ice, wind	Little or no control of lifeboat position/heading Lifeboat cannot be positioned correctly in the waves, heavy lifeboat motion (uncomfortable for passengers)	-Lifeboat pilot training/experience
MOB boat occupied when an accident occurs	-MOB boat have many tasks	-Long time to rescue -People getting seriously chilled	-Use both MOB-boats for redundancy
Passengers not noticing getting severely cold (core and extremities)	-Individual differences -Little or no experience with being cold -Sleeping	-Risk of injuries/fatalities	-Have buddies near you which can check on you -Leader onboard raft should keep overview.
Freezing body extremities	-Getting wet -Little clothing	-Frost bite leading to injuries	-Bring hats, gloves, etc. for backup in case. -Low threshold for returning people to *KV Svalbard* -Additional immersion suits in lifeboat for emergencies (for those not wearing suits during tests)
Pilot is incapable of leading	Injury, death, pilot has to abort exercise and return to ship.	Anarchy? Without leadership, people might not survive as long.	Find a new leader/next in command
Immersion suit integrity compromised	-Improper entering of suit --Openings not properly closed (zippers), etc.	-Exposure to cold water with potential injuries/chilling of body	-Buddy check on suit after putting it on, prior to test
Lack of sleep	Uncomfortable seating, stressful situation (physical and psychological)	Sleep deprivation	
CO and CO2 build-up inside lifeboat	Insufficient ventilation, many people breathing. Leak from exhaust system	Headaches, sleepiness, poor concentration, loss of attention, increased heart rate, slight nausea, oxygen deprivation.	-Detectors will measure CO and CO2 build-up and give alarms. -Opening hatches
High temperature inside lifeboat	Insufficient ventilation, many people generating heat	Dehydration caused by perspiration. Nausea, which can lead to vomiting, causing further dehydration.	-Opening hatches
Low temperature in lifeboat	Outside temperature.	Core body temperature of passengers dangerously low (hypothermia)	-Passengers wearing warm (waterproof) clothing
Hygiene	No toilet available	Insanitary conditions	Bucket or other solutions? -Bottles used in hospitals/small aircraft.
Clogging/blocking of ventilation	Warm and moist air from inside the lifeboat condensates and freezes around the ventilation outlet	Reduced ventilation, rapid deterioration of air quality	Opening hatches
Not enough food	Lifeboat not stocked	Hunger	-Ensure lifeboat carries enough food for exercise duration
Not enough water	Lifeboat not stocked	Thirst	-Ensure lifeboat carries enough water for exercise duration
Seasickness	Lifeboat movements	Vomiting, inducing dehydration	-Anti-seasickness medicine

		and starvation.	How to handle this if exercise participants starts vomiting?
Sea spray into lifeboat	The lifeboat hatches are open (ventilation, extracting persons from sea, etc.)	People get wet and cold. Water inside the lifeboat.	-Close hatches
Poor sight	Fog, snow squalls. Icing (sea spray) on windows	Navigation difficulties Possible collision	-Lifeboat pilot training
Sea spray icing on lifeboat	Sea spray combined with low temperatures	Skew loads, hinges and locks on hatches stuck, ventilation compromised.	
Rapid weather changes	-Weather in this region can change in minutes	-Exercise gets much more difficult -Stopping the might be necessary	-Check weather report prior to/during test -Procedure for rapid evacuation of all participants -Ensure that MOB boat is close to lifeboat during test, for emergency preparedness
Communication difficulties	-Wind noise -Many people talking at the same time -Routines for how to communicate -Radio equipment failure	-Important messages cannot be communicated via radio	-Backup radio equipment/battery -Clarify communication routines prior to test
Disturbance from other vessels in area, not part of exercise	-Nearby vessels not informed of test	-Interruption of test -Possible collisions and hazard for participants	-Notify any nearby vessels of the test -Establish safety zone around test area

Table A2. SARex Phase 1 Risk assessment – Life raft

Problem	**Cause**	**Consequence**	**Risk-reducing measures**
Life raft damaged	-Production error	-Equipment unusable	-Check prior to launch (Viking)
Disturbance from other vessels in area, not part of exercise	-Nearby vessels not informed of test	-Interruption of test -Possible collisions and hazard for participants	-Notify any nearby vessels of the test -Establish safety zone around test area
MOB boat lifting hook swinging after release	-Hook operator error -Rough seas	-Hook arrangement hits passengers in MOB boat, leading to injuries.	-Follow instructions -Detailed safety information and procedures from *KV Svalbard* crew
Falling into water during transfer between MOB boat and life raft	-Slippery surfaces -Distance between raft and MOB boat (e.g. due to poor mooring) -Rough seas	-Rapid cooling of persons in the sea	-*KV Svalbard* personnel entering life raft first, to assist with keeping the life raft and MOB boat close, and to help passengers from one vessel to the other
Many people ending up in the water at the same time	-Life raft integrity compromised -Capsizing -Etc.	-Mass injuries/hypothermia -Possible fatalities	-Establish procedures for rapid evacuation of all participants if necessary
MOB boat occupied when an accident occurs	-MOB boat have many tasks	-Long time to rescue -People getting seriously chilled	-Use both MOB-boats for redundancy
Long distance from MOB boat to life raft during test	-MOB-boat have many tasks -MOB-boat not on the water during test	-Long time to rescue -People getting seriously chilled -Long rescue time if people fall into the sea	-Ensure that MOB boat is close to raft during test for emergency preparedness -Use both MOB-boats for redundancy
Rescuing passengers from sea to life raft	-Insufficient arrangements on life raft for extraction of people	-Difficult/impossible to rescue survivors from sea	-Ensure that MOB boat is close to raft during test for emergency preparedness
Insufficient observation during test (of the entire area)	-Poor overview	-People fall into water without someone noticing	-Crew onboard *KV Svalbard* and MOB boats ensures lookout
Immersion suit integrity compromised	-Improper entering of suit --Openings not properly closed (zippers), etc.	-Exposure to cold water with potential injuries/chilling of body	-Buddy check on suit after putting it on, prior to test
Poor sight	-Fog -Snow squalls -Sea spray	-Impact with drift ice -Difficulties with keeping an overview (polar bear lookouts spot/locating participants falling into sea, etc.)	-Abort test if weather conditions gets too severe -Ensure that MOB boat is close to raft during test for emergency preparedness

CO2 build-up inside life raft	-Insufficient ventilation, combined with many people breathing.	-Headaches, sleepiness, poor concentration, loss of attention, increased heart rate, slight nausea, oxygen deprivation.	-Opening the canopy -Air quality measurement instruments onboard life raft -Ensure control of air vents.
High temperature inside life raft	-Insufficient ventilation, combined with many people generating heat	-Heat stress: Dehydration caused by perspiration. Nausea, which can lead to vomiting, causing further dehydration.	-Opening canopy when necessary
Low temperature in life raft	-Outside temperature.	-Core body temperature of passengers drops dangerously low (hypothermia)	-Bring hats, gloves, etc. for backup in case. -Low threshold for returning people to *KV Svalbard* -Ensure that MOB boat is close to raft during test for emergency preparedness
Rapid weather changes	-Weather in this region can change in minutes	-Exercise gets much more difficult -Stopping the might be necessary	-Check weather report prior to/during test -Procedure for rapid evacuation of all participants -Ensure that MOB boat is close to raft during test, for emergency preparedness
Passengers not noticing getting severely cold (core and extremities)	-Individual differences -Little or no experience with being cold -Sleeping	-Risk of injuries/fatalities	-Have buddies near you which can check on you -Leader onboard raft should keep overview.
Freezing body extremities	-Getting wet -Little clothing	-Frost bite leading to injuries	-Bring hats, gloves, etc. for backup in case. -Low threshold for returning people to *KV Svalbard* -Additional immersion suits in life raft for emergencies (for those not wearing suits during tests)
Medical problems of passengers	-Latent health issues -Other medical condition factors	-Possible medical emergencies for participants	-Low threshold for returning people to *KV Svalbard*
Seasickness	-Lifeboat movements -Seasickness medicine not effective immediately	Vomiting, inducing dehydration and starvation.	-Anti-seasickness medicine -Take medicine prior to test -Check with KV personnel on advice
Not enough food	-Lifeboat not stocked	-Hunger -Exercise must be stopped	-Ensure lifeboat carries enough food for exercise duration
Not enough water	-Lifeboat not stocked	-Thirst -Exercise must be stopped	-Ensure lifeboat carries enough water for exercise duration
Hygiene	-No toilet available	-Insanitary conditions	-Bucket or other solutions? -Transport people with MOB boat to *KV Svalbard* for toilet visits
Lack of sleep	Uncomfortable seating, stressful situation (physical and psychological)	-Sleep deprivation: Reduced cognitive abilities Ability to take care of yourself reduced, etc.	-Try to sleep when possible
Polar bear attack	-Animal curiosity/hunger/threatened	-Raft puncture -Injuries/fatalities	-Polar bear guard (*KV Svalbard*) -Armed personnel onboard MOB-boat -Flares/signal rockets -Situation awareness
Walrus/orca attack	-Animal curiosity/hunger/threatened	-Raft puncture -Injuries/fatalities	-Armed personnel onboard MOB-boat -Flares/signal rockets -Situation awareness